BIODIVERSITAS
Volume 27, Number 4, April 2026
Pages: 11

ISSN: 1412-033X
E-ISSN: 2085-4722
https://doi.org/10.13057/biodiv/d270408

Biodiversity and carbon stock analysis in the high conservation value forest within the oil palm plantation setting in Central Kalimantan, Indonesia

SITI MAIMUNAH[1,♥], YOVI AVIANTO[2], AMIR NOVIYANTO[2], FADHLULLAH RAMADHANI[3], VALENSI KAUTSAR[2], YOHANA THERESIA MARIA ASTUTI[2], SRI GUNAWAN[2], JH SAMEK[4]

[1]Faculty of Forestry, Institut Pertanian Stiper. Jl. Nangka II, Sleman 55281, Yogyakarta, Indonesia. Tel.: +62-274-885580,
♥email: sitimararil@gmail.com
[2]Faculty of Agriculture, Institut Pertanian Stiper. Jl. Nangka II, Sleman 55281, Yogyakarta, Indonesia
[3]National Research and Innovation Agency (BRIN). Jl. M.H. Thamrin No. 8, Jakarta Pusat 10340, Jakarta, Indonesia
[4]GOES, Faculty of Forestry, Michigan State University. 480 Wilson Rd, East Lansing 48824, Michigan, United States

Manuscript received: 7 November 2024. Revision accepted: 7 April 2026.

Abstract. *Maimunah S, Avianto Y, Noviyanto A, Ramadhani F, Kautsar V, Astuti YTM, Gunawan S, Samek J. 2026. Biodiversity and carbon stock analysis in the high conservation value forest within the oil palm plantation setting in Central Kalimantan, Indonesia. Biodiversitas 27 (4): d270408. https://doi.org/10.13057/biodiv/d270408*. High Conservation Value Forests (HCVFs) within oil palm landscapes play a crucial role in maintaining biodiversity and ecosystem services, including carbon storage. However, empirical evidence quantifying biodiversity-carbon co-benefits in industrial plantation contexts remains limited in Indonesia. This study assessed plant biodiversity, wildlife presence, and aboveground carbon stock in a 65-ha HCVF managed by a private enterprise in Kotawaringin Timur, Central Kalimantan, Indonesia. Field surveys were conducted using an 8% sampling intensity across 13 nested plots (50 m × 80 m). Tree and seedling diversity were evaluated using Margalef, Menhinick, Shannon-Wiener, Simpson, and evenness indices. Carbon stock was estimated based on diameter and height measurements using the USAID-MSU Biodiversity and Carbon Potential Calculator. Wildlife presence was documented through direct and indirect field evidence. A total of 68 tree species and 26 seedling species were recorded. Shannon diversity indices indicated high diversity at the tree level ($H' = 3.31$) and moderate diversity at the seedling level ($H' = 2.41$), with high species evenness ($E>0.70$). The forest was dominated by secondary Dipterocarp species. Average aboveground carbon stock reached 191.44 tC ha^{-1}, corresponding to a total carbon reserve of 12,443.72 tC across the HCVF area. Several protected wildlife fauna, including hornbills, pangolins, and gibbons, were identified. These findings demonstrate that HCVFs embedded within oil palm concessions can simultaneously support biodiversity conservation and climate mitigation. Effective protection of such areas is therefore essential for strengthening sustainability performance and achieving conservation commitments in tropical agricultural landscapes.

Keywords: Biodiversity indices, carbon stock, dipterocarp forest, high conservation value forest, oil palm landscape

INTRODUCTION

The rapid expansion of oil palm plantations has raised substantial ecological concerns, particularly related to biodiversity loss and increased greenhouse gas emissions (Drewer et al. 2021, 2024). The extensive deforestation of tropical forests is a significant contributor to the loss of biodiversity and to global warming. Indonesia, as the world's largest palm oil producer, faces growing pressure to balance economic development with environmental sustainability (Herningtyas 2021; Amri et al. 2023). In response, sustainability frameworks such as the High Conservation Value (HCV) approach have been widely adopted. High Conservation Value Forests (HCVFs) are areas that contain biological, ecological, social, or cultural values of outstanding significance at national, regional, or global levels (Kwatrina et al. 2018; Nasution et al. 2023). These values may include habitats for rare, threatened, or endangered species; intact or rare ecosystems; critical ecosystem services such as watershed protection and erosion control; and areas of importance for community livelihoods or cultural heritage. The HCV framework encompasses species diversity, landscape-scale ecosystems, threatened habitats, ecosystem services, community needs, and cultural values (Sahana et al. 2025). Within oil palm concessions, HCVFs often function as ecological refugia that preserve remnant forest patches embedded in intensively managed agricultural matrices (Mijiarto et al. 2023; Ramlah et al. 2024). Previous studies have shown that such forest fragments can maintain relatively high plant species diversity and provide habitat for forest-dependent and threatened fauna (Mohd-Azlan 2019; Kasper et al. 2024). HCVFs within tropical forest settings might contribute significantly to climate regulation through carbon sequestration (Austin et al. 2017; Fleiss et al. 2020). HCVFs may therefore play a dual role by supporting both biodiversity conservation and carbon storage at the landscape scale. Biodiversity monitoring is a fundamental component of HCVF management, as species richness, diversity indices, and wildlife presence are key indicators of ecological quality and conservation effectiveness. Pusparini et al. (2023) stated that areas with high or unique biodiversity values are prioritized for protection. Alongside biodiversity, forest carbon storage represents a critical ecosystem service, reflecting the capacity of vegetation to absorb atmospheric carbon dioxide and mitigate climate change (Fleiss et al. 2020). Carbon storage varies among forest types and species compositions and is strongly influenced by forest structure, stand density, and disturbance history (Tuan et al. 2022; Chisholm and Gray 2024). The HCV approach is applied across various land-based sectors, including forestry, mining, infrastructure, and energy (Budiharta 2010; Fiqa et al. 2018), its implementation within oil palm plantations is particularly important due to the scale of land conversion involved (Mijiarto et al. 2023; Afrianti and Pakpahan 2024). An example of an oil palm plantation has integrated HCVF management into its sustainability strategy. This includes the protection of remnant forests, conservation of wildlife and rare tree species, support for social forestry initiatives, and community-based development programs. The establishment and management of HCVFs have therefore become a central element of sustainability practices within the company's plantation landscapes. Despite the widespread adoption of HCVFs in policy and sustainability frameworks, empirical research that simultaneously quantifies both biodiversity and carbon stocks in company-managed HCVF landscapes remains limited. Systematic reviews of forest management research indicate that empirical evidence linking biodiversity conservation and carbon sequestration under certification or HCV frameworks is scattered and under-represented in the peer-reviewed literature, particularly in tropical Asia, where such landscapes are most extensive (Wolff and Schweinle 2022).

Moreover, research on carbon-biodiversity co-benefits has predominantly focused on general forest fragmentation and community-based or REDD+-related forest governance, rather than on industry-managed High Conservation Value (HCV) set-asides within plantation concessions. Reviews on forest fragmentation (including in Indonesia) emphasize biodiversity impacts and landscape configuration as the main analytical lens, often without integrated carbon–biodiversity quantification in certified plantation set-asides (Gunawan et al. 2024). Recent studies demonstrate measurable biodiversity and carbon benefits of such set-asides in certified plantations (Senior et al. 2015; Mitchell et al. 2018; Scriven et al. 2019; Fleiss et al. 2020). This imbalance highlights a continuing need for on-the-ground, integrated assessments of biodiversity and carbon within industrial HCV contexts (Deere et al. 2018). Consequently, there is a strong need for peer-reviewed empirical data to bolster scientific validation and inform broader policy and sustainability. Therefore, this study aims to integrate biodiversity and carbon stock analyses in High Conservation Value Forest within an oil palm plantation setting.

MATERIALS AND METHODS

Study area

The study was conducted in a 65-ha High Conservation Value Forest (HCVF) located within the concession of a private oil palm company in Pundu Village, Kotawaringin Timur District, Central Kalimantan, Indonesia (Figure 1). The High Conservation Value Forest (HCVF) is located at approximately 50 m above sea level and is distributed across three separate sites characterized by gentle topography, riparian zones, and periodically waterlogged conditions. Several areas are intersected by river channels, while forest degradation is evident near road access. Part of the concession has been allocated for conservation management. The HCVF historically functions as a watershed protection area and was designated for conservation under the company's Environmental Impact Assessment (AMDAL) framework in Indonesia. Conservation programs implemented in the area include wildlife monitoring, monitoring of wildlife food tree species, protection of rare trees, fire patrols, and community livelihood development initiatives.

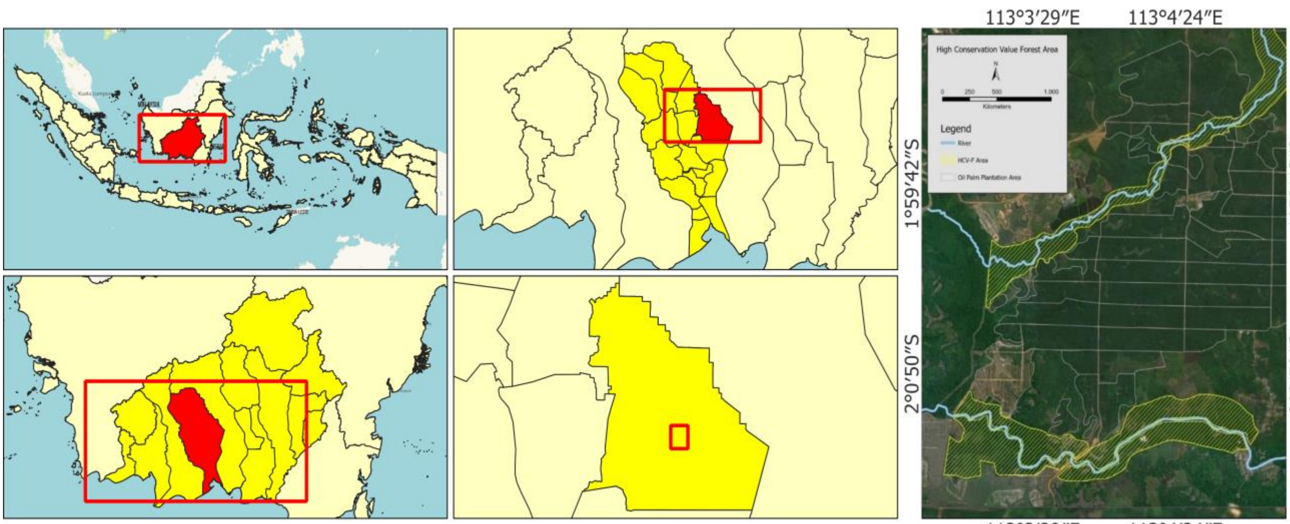

Figure 1. Map of HCVF Area of an oil palm concession in Pundu Village, Kotawaringin Timur District, Central Kalimantan, Indonesia

Research procedure

Sampling design

Biodiversity and carbon assessments were carried out using ecosystem service assessment tools developed by Michigan State University in collaboration, which were then modified by Maimunah et al. (2021). USAID (United States Agency for International Development), through its environmental programs in Indonesia, has supported the development of tools for assessing ecosystem services, including carbon and biodiversity calculators based on tree species diversity and vegetation composition within a given area.

In this study, the tool was applied as a standardized, plot-based inventory spreadsheet in which field observations were entered separately for trees and seedlings. Trees with DBH >5 cm were recorded in 20 m × 20 m plots, whereas seedlings with DBH < 5 cm were recorded in nested 2 m × 2 m subplots. For each plot, the tool compiles species identity and the number of individuals per species, and also records additional understory vegetation components such as lianas, shrubs, ferns, pandan, and other herbaceous plants. Based on these inputs, the spreadsheet automatically summarizes key biodiversity metrics, including species richness, Menhinick's richness index, Margalef's richness index, Shannon diversity index, Simpson diversity index, species frequency, relative abundance, and plot-level rankings of dominant species. Within the modified framework used in this study, the vegetation inventory also served as the basis for estimating ecosystem service values, including carbon-related attributes, thereby enabling a standardized assessment of biodiversity and carbon across the HCVF.

An 8% sampling intensity was applied, resulting in 13 observation plots that were systematically distributed across the HCVF to represent site heterogeneity. Each plot followed a nested sampling design with a main plot size of 50 × 80 m. Biodiversity assessment was divided into flora and fauna components as detailed below.

Floristic diversity assessment

Flora was classified into woody and non-woody vegetation. Non-woody and useful plants were recorded based on encounter frequency within the observation area. Woody vegetation was assessed quantitatively using the USAID-MSU Biodiversity Calculator.

Tree species diversity plots were established following the design illustrated in Figure 2. Trees with a diameter at breast height (DBH) ≥5 cm were measured within the main plots. Poles (DBH 10-19 cm) were measured in 10 m × 10 m subplots, saplings (DBH 5-9 cm) in 5 m × 5 m subplots, and seedlings were counted in 2 m × 2 m subplots. Tree diameter was measured at 1.3 m above ground level (DBH), with adjustments made for irregular stems according to standard forestry procedures. Species identification was conducted in the field with assistance from experienced local botanists and validated using relevant floristic references. Species richness and diversity were quantified using Margalef, Menhinick, Shannon-Wiener (H′), Simpson (D), and Pielou's evenness (E) indices, calculated using the USAID-MSU Biodiversity Calculator.

Faunistic diversity assessment

Fauna diversity was assessed through direct and indirect observation methods. Direct observations included visual sightings and identification of animal vocalizations, while indirect evidence included footprints, feces, nests, feathers, and scratch marks. Observations were conducted along existing forest trails, covering distances determined by visibility and accessibility within the forest. Local community members with expertise in wildlife behavior and species recognition assisted in the identification process. All wildlife records were verified using authoritative zoological literature to ensure scientific accuracy.

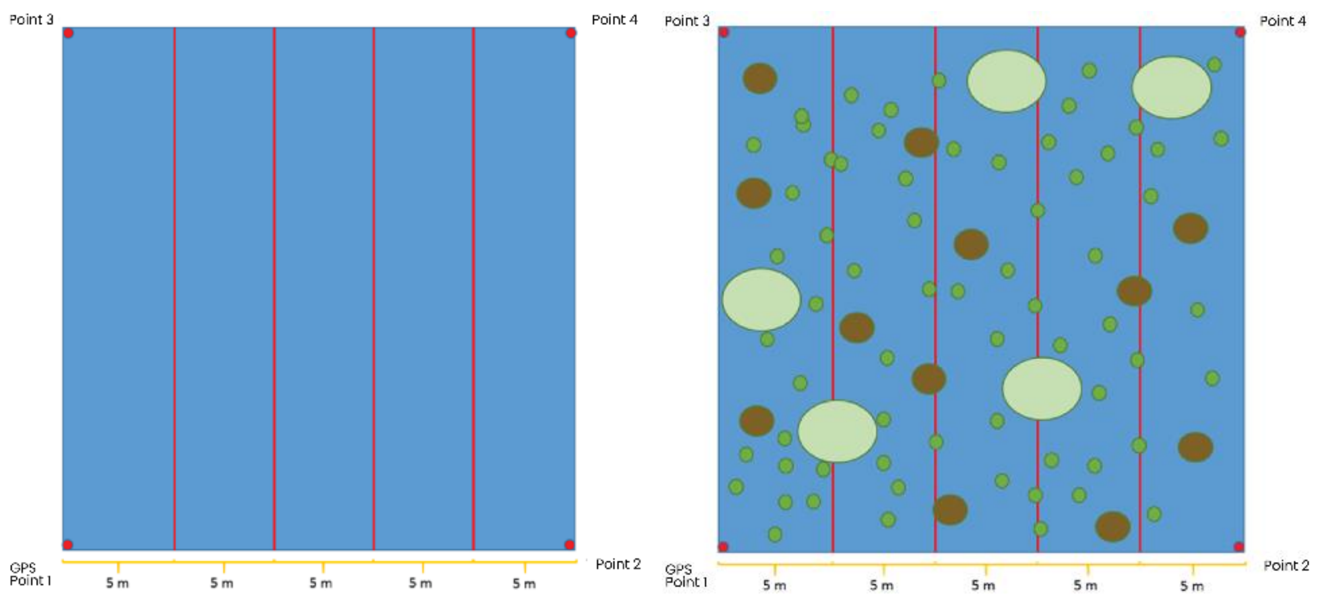

Figure 2. Design of sampling plot to collect tree species diversity data

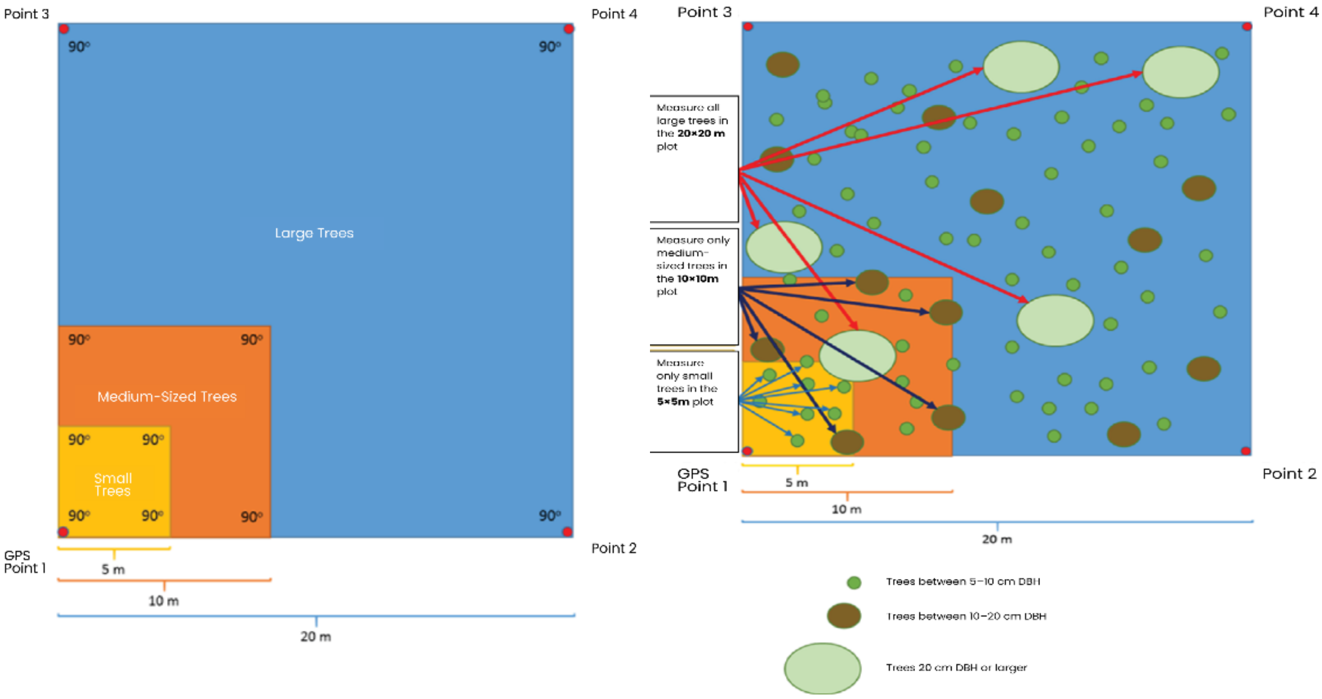

Figure 3. Design of sampling plot to collect carbon data

Carbon stock estimation

Aboveground carbon stock was estimated using a carbon calculator developed by Michigan State University (USAID LESTARI 2018), following methodologies described by Maimunah et al. (2024). Carbon sampling employed the same nested plot design used for vegetation assessment (Figure 3). Tree biomass data were collected by measuring the diameter and height of trees within the 50 m × 80 m plots, while poles, saplings, and seedlings were measured or counted in their respective subplots. Carbon stock was expressed as tons of carbon per hectare (tC ha^{-1}) and extrapolated to the total HCVF area. Statistical parameters, including mean carbon stock, standard deviation, standard error, and confidence intervals at the 95% confidence level, were calculated using a t-distribution.

Data analysis

All biodiversity and carbon data were processed using the USAID-MSU Biodiversity and Carbon Potential Calculators. Descriptive statistics and diversity indices were used to evaluate vegetation structure, species composition, and ecosystem carbon storage. Results were subsequently interpreted in relation to forest condition, conservation value, and sustainability implications within oil palm plantation landscapes.

RESULTS AND DISCUSSION

Floristic diversity and forest structure

The High Conservation Value Forest (HCVF) in this study supported 68 tree species (DBH ≥5 cm) and 26 seedling species across a total sampled area of 5.2 ha, representing 8% of the 65-ha HCVF. This indicates considerable floristic richness for a secondary forest fragment embedded within an oil palm-dominated landscape. The observed tree-level Shannon diversity index (H′ = 3.31) falls within the upper range reported for secondary lowland tropical forests in Borneo and Southeast Asia, where values typically range from 2.5 to 3.5 depending on disturbance intensity and forest age (Gibson et al. 2011; Slik et al. 2015). Such diversity values indicate a structurally complex forest community with relatively high ecological stability, despite its location within a plantation matrix (Table 1).

Seedling diversity was lower (*H′* = 2.41), suggesting selective regeneration and potential filtering effects related to canopy structure and historical disturbance. Similar regeneration patterns have been observed in tropical rainforest remnants and forest fragments within oil palm-dominated landscapes, where edge-driven changes in microclimate and forest structure can influence recruitment dynamics and community composition near forest-plantation interfaces (Meijaard et al. 2020; Ordway and Asner 2020; Nunes et al. 2021; Anderson et al. 2022). Furthermore, evidence from Borneo shows that ecological impacts associated with oil palm edges can extend into adjacent forests, potentially constraining regeneration processes in edge-proximal areas (Scriven et al. 2018). Consistent with this, patterns of richness often differ among seedlings, saplings, and adult trees in rainforest remnants, indicating that regeneration may lag behind tree-level diversity (Stride et al. 2018). Nevertheless, the presence of Dipterocarpaceae seedlings indicates ongoing forest recovery and long-term conservation potential.

High Simpson and Evenness indices (>0.70) at both growth stages indicate low dominance and relatively even species distribution, contrasting with degraded forest fragments which are typically dominated by a few pioneer species (Adinugroho et al. 2022; Rodríguez-León et al. 2022). This evenness suggests that competitive exclusion has not occurred and that forest structure remains functionally intact. At the family level, 24 tree families were recorded in the HCVF, with Dipterocarpaceae, Euphorbiaceae, and Myrtaceae being the most dominant (Figure 4). Dipterocarpaceae exhibited the highest representation, reflecting its ecological role as a keystone family in lowland tropical forests of Borneo. The prominence of this family is particularly important as dipterocarps contribute disproportionately to canopy formation, biomass accumulation, and long-term carbon storage (Slik et al. 2015; Prohaska et al. 2023; Kristianto 2025). Euphorbiaceae and Myrtaceae, which are commonly associated with secondary and recovering forests, further indicate that the HCVF represents a mid-to-late successional forest stage. Similar family dominance patterns have been documented in logged and regenerating Bornean lowland forests, where structural recovery is underway (Basyuni et al. 2019; Rahayu et al. 2022).

In addition to Shannon-Wiener and Simpson indices, the richness indices also showed clear differences between trees and seedlings. Tree richness was higher than seedling richness, as reflected by the greater number of species, Menhinick's richness, and Margalef's richness values in the tree layer. This indicates that the forest still retains high floristic diversity at the canopy level, while regeneration in the understory is represented by fewer species. The evenness values were relatively high in both growth stages, suggesting that species were fairly evenly distributed and that no single species strongly dominated the community. However, the slightly lower evenness in seedlings indicates that regeneration was somewhat less balanced than the tree layer. The total number of individuals was also much higher in trees than in seedlings, which reflects differences in stand structure and regeneration density. In addition, the presence of lianas, shrubs, ferns, pandan, and other herbaceous plants shows that the HCVF still maintains a relatively complex vegetation structure, which is important for supporting ecological functions in a fragmented forest landscape (Maimunah et al. 2024).

Figure 4 shows that the HCVF retained a broad family-level composition, with Euphorbiaceae, Myrtaceae, Dipterocarpaceae, and Lauraceae as the most represented families. This pattern suggests that the forest fragment still maintains substantial floristic heterogeneity rather than being dominated by only a few disturbance-tolerant taxa. In tropical forests of Borneo and Southeast Asia, family-level diversity of this kind is commonly associated with structurally heterogeneous stands that support multiple regeneration niches and ecological functions (Tng et al. 2016).

The presence of Dipterocarpaceae is especially important because this family is a defining component of Southeast Asian lowland rainforests and contributes strongly to canopy structure, biomass accumulation, and carbon storage (Ng et al. 2021). Its continued representation in the HCVF indicates that the site still retains key characteristics of native lowland forest despite being surrounded by oil palm (Luskin et al. 2017). At the same time, the strong representation of Euphorbiaceae and Myrtaceae suggests that the forest also bears the signature of secondary succession and past disturbance. These families are frequently well represented in regenerating tropical forests, so their prominence here is consistent with a recovering secondary forest that still preserves native forest identity (Tng et al. 2016; Mukul et al. 2020). The relatively large "others" category further indicates that many families are represented by only a few species each, which is typical of species-rich tropical forests and reflects compositional complexity rather than simplification. The dominance of the Euphorbiaceae family such as Macarangan indicates that the area was once cleared. Macaranga species from Euphorbiaceae and Myrtaceae are pioneer species that will be the first to grow when the area is open and will naturally die once it has reached climax growth.

Overall, the family distribution indicates that this HCVF functions as more than a remnant patch of trees. It still supports a taxonomically diverse forest assemblage with both late-forest elements, such as Dipterocarpaceae, and families commonly associated with regeneration, reinforcing its role as an important biodiversity refuge within an oil palm-dominated landscape (Waddell et al. 2020). Forest remnants in oil palm landscapes are widely recognized as critical for maintaining ecological structure and reducing biodiversity loss in otherwise simplified production systems (Luskin et al. 2017).

Table 1. Summary of plant biodiversity indices in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Metric	Trees (>5 cm DBH)	Seedlings (<5 cm DBH)	Other flora/inventory notes
Species richness	68	26	13 tree plots and 13 seedling plots were inventoried
Menhinick's richness	1.680	1.579	Tree plots also recorded lianas/climbers and shrubs
Margalef richness	9.052	4.463	Seedling plots also recorded ferns, pandan, small shrubs, and other herbs
Shannon-Wiener (H′)	3.315	2.405	
Simpson (D)	0.936	0.832	
Evenness (E)	0.786	0.738	
Total individuals	1639	271	Lianas/climbers: 7; shrubs: 36; ferns: 17; pandan: 26; small shrubs: 20; other herbaceous plants: 25

Important value index

The IVI results show that the tree layer was dominated by *Eugenia* spp., followed by *Hevea brasiliensis*, *Pternandra rostrata*, and *Nauclea subdita*, whereas the sapling layer was strongly dominated by *Eugenia* spp., *P. rostrata*, and *Syzygium* spp. (Tables 2 and 3). This pattern suggests that the HCVF is currently maintained by a mixture of native secondary-forest taxa and disturbance-associated species. The repeated prominence of Myrtaceae members in both tree and sapling strata indicates active regeneration and good persistence under present site conditions, while the occurrence of *H. brasiliensis* among the most important tree species likely reflects a legacy of past human disturbance or former land-use influence within the forest fragment. In secondary forests, high diversity can recover relatively well, but species composition often remains shaped by past disturbance and differs from less disturbed stands for decades (Pransiska et al. 2016; Hayward et al. 2021).

The contrast between tree and sapling IVI is also ecologically important (Tables 2 and 3). Several species that were prominent in the tree layer remained important in the sapling layer, especially *Eugenia* spp., *P. rostrata*, *Gardenia elata*, and *Lophopetalum javanicum*. This suggests that part of the current canopy composition is still being recruited into the younger layer, which is a positive sign for stand continuity. At the same time, the stronger concentration of IVI in fewer sapling species indicates that regeneration is somewhat more selective than the adult tree composition. Such shifts are common in disturbed tropical forests, where understory recruitment is filtered by light conditions, edge effects, and dispersal constraints (Anand et al. 2010; Hua et al. 2024). In oil palm landscapes, retained forest patches remain important because they preserve regeneration processes that would be lost in the surrounding monoculture matrix (Rahayu et al. 2022).

Table 4 further strengthens the conservation importance of this HCVF. Although many recorded species were classified as Least Concern, the presence of Near Threatened and Vulnerable species, especially several Dipterocarpaceae such as *Hopea beccariana*, *Rubroshorea balangeran*, and *Rubroshorea rugosa*, shows that this forest fragment still supports taxa of elevated conservation concern. This is highly significant because dipterocarps are key structural elements of Southeast Asian lowland forests and are also among the groups most affected by logging and forest conversion in Borneo (Ang et al. 2016; Hayward et al. 2021). Their persistence in the study site indicates that the HCVF functions not only as a refuge for regionally important forest tree species, particularly lowland dipterocarps and other Bornean forest taxa, but also as habitat for forest-associated fauna that are known to depend on remnant forest cover within oil palm landscapes (Scriven et al. 2015). This interpretation is consistent with studies from Borneo and Southeast Asia showing that lowland dipterocarp forests support exceptionally high biodiversity, while forest-dependent birds, mammals, and amphibians are consistently more strongly associated with retained forest patches than with oil palm stands (Scriven et al. 2018; Simamora et al. 2021; William et al. 2023).

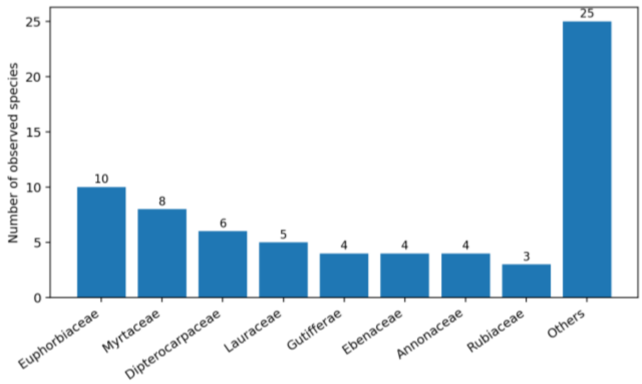

Figure 4. Distribution of tree families in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Table 2. Tree species with the greatest IVI (%) in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Rank	Local name	Scientific name	Family	Total individuals	Relative frequency	IVI
1	*Jambu putih*	*Eugenia* spp.	Myrtaceae	317	6.42	12.30
2	*Karet*	*Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	76	1.07	9.53
3	*Kamasulan*	*Pternandra rostrata* (Cogn.) M.P.Nayar	Melastomaceae	106	5.35	7.71
4	*Gempol*	*Nauclea subdita* (Korth.) Steud.	Rubiaceae	107	3.21	7.18
5	*Perupuk*	*Lophopetalum javanicum* (Zoll.) Turcz.	Celastraceae	100	2.67	7.13
6	*Pupuh pelanduk*	*Neoscortechinia kingii* (Hook.f.) Pax & K.Hoffm.	Euphorbiaceae	72	1.60	6.95
7	*Kalapapa*	*Vitex pubescens* B.Heyne ex Wall.	Verbenaceae	73	2.14	6.20
8	*Jambu merah*	*Syzygium* spp.	Myrtaceae	63	4.28	6.03
9	*Hampuak*	*Baccaurea bracteata* Müll.Arg.	Euphorbiaceae	62	4.28	6.00
10	*Niniranda*	*Gardenia elata* Ridl.	Rubiaceae	39	4.81	5.78

Table 3. Saplings species with the greatest IVI (%) in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Rank	Local name	Scientific name	Family	Total individuals	Relative frequency	IVI
1	*Jambu putih*	*Eugenia* spp.	Myrtaceae	100	13.46	27.90
2	*Kamasulan*	*Pternandra rostrata* (Cogn.) M.P.Nayar	Melastomaceae	26	11.54	15.92
3	*Jambu merah*	*Syzygium* spp.	Myrtaceae	29	5.77	15.54
4	*Niniranda*	*Gardenia elata* Ridl.	Rubiaceae	19	9.62	13.46
5	*Perupuk*	*Lophopetalum javanicum* (Zoll.) Turcz.	Celastraceae	13	5.77	10.15
6	*Kayu sapat*	*Trichilia hirta* L.	Meliaceae	12	5.77	9.81
7	*Gandis*	*Garcinia parvifolia* (Miq.)	Gutifferae	6	1.92	7.99
8	*Aciw*	*Garcinia acuminata* Planch. & Triana	Gutifferae	6	1.92	7.99
9	*Kahoi*	*Rubroshorea balangeran* (Korth.) P.S.Ashton & J.Heck.	Dipterocarpaceae	7	3.85	7.38
10	*Pampaning pasang*	*Lithocarpus elegans* Blume) Hatus. ex Soepadmo	Fagaceae	7	3.85	7.38

Table 4. Conservation status of plant species in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Local name	Scientific name	Family	IUCN category
Kambalitan	*Polyalthia lateriflora* (Blume) Kurz	Annonaceae	LC
Pantung	*Dyera polyphylla* (Miq.) Steenis	Apocynaceae	LC
Resak air	*Cotylelobium lanceolatum* Craib	Dipterocarpaceae	LC
Keruing kaca	*Dipterocarpus oblongifolius* Blume	Dipterocarpaceae	LC
Kayu arang	*Diospyros areolata* King & Gamble	Ebenaceae	LC
Jinjit	*Calophyllum apetalum* Willd.	Gutifferae	LC
Aciw	*Garcinia acuminata* Planch. & Triana	Gutifferae	LC
Manggis hutan	*Garcinia beccarii* Pierre	Gutifferae	LC
Gandis	*Garcinia parvifolia* (Miq.) Miq.	Gutifferae	LC
Tunjung	*Actinodaphne borneensis* Meisn.	Lauraceae	LC
Medang air	*Nothaphoebe umbelliflora* (Blume) Blume	Lauraceae	LC
Medang telur	*Bhesa paniculata* Arn.	Lauraceae	LC
Mandarahan putih	*Horsfieldia irya* (Gaertn.) Warb.	Myristicaceae	LC
Mandarahan merah	*Horsfieldia irya* (Gaertn.) Warb.	Myristicaceae	LC
Katiau	*Palaquium pseudorostratum* H.J.Lam	Sapotaceae	LC
Meranti bitik	*Shorea pauciflora* King	Dipterocarpaceae	NT
Ehang haduk	*Diospyros maingayi* (Hiern) Bakh.	Ebenaceae	NT
Karipak nangka	*Artocarpus kemando* Miq.	Moraceae	NT
Lewang	*Planchonella malaccensis* (C.B.Clarke) Swenson	Sapotaceae	NT
Keruing Sindur/Uhit	*Dipterocarpus borneensis* Slooten	Dipterocarpaceae	NT
Merawan	*Hopea beccariana* Burck	Dipterocarpaceae	VU
Kahoi	*Rubroshorea balangeran* (Korth.) P.S.Ashton & J.Heck.	Dipterocarpaceae	VU
Meranti batu	*Rubroshorea rugosa* (F.Heim) P.S.Ashton & J.Heck.	Dipterocarpaceae	VU
Ulin	*Eusideroxylon zwageri* Teijsm. & Binn.	Lauraceae	VU

Note: IUCN category indicates the global conservation status of each species according to the IUCN Red List. LC: Least Concern, denotes species with low risk of extinction, NT: Near Threatened, denotes species that are close to meeting the criteria for a threatened category, and VU: Vulnerable, denotes species considered to face a high risk of extinction in the wild

The occurrence of *Eusideroxylon zwageri* (Bornean ironwood) is noteworthy because this species is classified as Vulnerable (VU) on the IUCN Red List (Qie et al. 2019). Together with the threatened dipterocarps, its occurrence suggests that the fragment still retains elements of mature forest identity despite its secondary status. From a management perspective, this means the HCVF has value beyond local species richness alone: it contributes to the retention of threatened tree assemblages that are increasingly rare in converted lowland landscapes (Hua et al. 2024). Therefore, species with high IVI should not be interpreted only as indicators of dominance, but also as indicators of regeneration trajectories, while the threatened taxa recorded in Table 4 underline the need for continued protection and low-disturbance management of the site.

Potential uses of plants

The use of plants with a high rarity status tends to have multiple uses, such as being sought after for having good quality wood for construction, the wood industry, traditional medicine, which increases their threat level, especially if the plant species is also a food source for wildlife (Table 5). Of course, this also affects the scarcity of wildlife because they lose their food just because it is cut down by humans. The massive hunting of Dipterocarpaceae species is also a major cause of the scarcity of these species, including in the company's HCVF areas where the company also has a responsibility to maintain the sustainability of these species, especially these rare species, to ensure they continue to exist. The perpetrators of this logging could be from the surrounding community who take them on-site without permission.

Fauna presence and conservation value

The documentation of protected and forest-dependent fauna, including pangolins (*Manis javanica* Desmarest, 1822), hornbills, gibbons, and white-bellied sea eagles (*Haliaeetus leucogaster* (Gmelin, 1788)), confirms the functional role of the HCVF as an important wildlife habitat within the oil palm landscape (Table 6).

Previous studies have shown that forest patches retained within oil palm plantations can act as ecological refugia and movement corridors for vertebrates, particularly when forest structural complexity and landscape connectivity are maintained.

Long-term forest loss and fragmentation have been shown to reduce functionally connected habitat for Bornean birds and mammals, underscoring the importance of structurally intact forest patches within agricultural matrices (Ocampo-Peñuela et al. 2020). Empirical evidence from vertebrate and amphibian communities further indicates that edge effects and landscape configuration strongly influence species persistence in and around forest fragments embedded in oil palm plantation (Scriven et al. 2018; Kasper et al. 2024). In addition, forest set-aside areas such as riparian and peat swamp forests support distinct bird assemblages compared with adjacent oil palm land, reinforcing the refugial value of conserved woodland remnants (Erniwati et al. 2016; Amit et al. 2023).

Table 5. Potential uses plants in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Local name	Scientific name	Uses
Kambalitan	*Polyalthia lateriflora*	Wildlife food and construction
Pantung	*Dyera polyphylla* (Miq.) Steenis	NTFP and wood industry
Resak air	*Cotylelobium lanceolatum* Craib	Construction
Keruing kaca	*Dipterocarpus oblongifolius* Blume	Construction
Kayu arang	*Diospyros areolata* King & Gamble	Wildlife food and construction
Jinjit	*Calophyllum apetalum* Willd.	Medicine, wildlife food and construction
Aciw	*Garcinia acuminata* Planch. & Triana	Wildlife food and construction
Manggis hutan	*Garcinia beccarii* Pierre	Wildlife food and construction
Gandis	*Garcinia parvifolia* (Miq.)	Wildlife food and construction
Tunjung	*Actinodaphne borneensis* Meisn.	Construction
Medang air	*Nothaphoebe umbelliflora* (Blume) Blume	Construction
Medang telur	*Bhesa paniculata* Arn.	Construction
Mandarahan putih	*Horsfieldia irya* (Gaertner) Warb.	Medicine and construction
Mandarahan merah	*Horsfieldia irya* (Gaertn.) Warb.	Medicine and construction
Katiau	*Palaquium pseudorostratum* H.J.Lam	Wildlife food and construction
Meranti bitik	*Shorea pauciflora* King	Construction
Ehang haduk	*Diospyros maingayi* (Hiern) Bakh.	Construction
Karipak nangka	*Artocarpus kemando* Miq.	Wildlife food and construction
Lewang	*Planchonella malaccensis* (C.B.Clarke) Swenson	NTFP and construction
Keruing sindur/Uhit	*Dipterocarpus borneensis* Slooten	Construction
Merawan	*Hopea beccariana* Burck	Construction
Kahoi	*Rubroshorea balangeran* (Korth.) P.S.Ashton & J.Heck.	Construction
Meranti batu	*Rubroshorea rugosa* (F.Heim) P.S.Ashton & J.Heck.	Construction
Ulin	*Eusideroxylon zwageri* Teijsm. & Binn.	Medicine and construction
Piais	*Nephelium maingayi* Hien	Wildlife food and construction

Table 6. Fauna species and its conservation status in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Local name	Scientific name	IUCN category
Sunda pangolin	*Manis javanica* Desmarest, 1822	Critically Endangered (CR)
Sun bear	*Helarctos malayanus* (Raffles, 1822)	Vulnerable (VU)
Palawan hornbill	*Anthracoceros marchei* Oustalet, 1885	Vulnerable (VU)
Rhinoceros hornbill	*Buceros rhinoceros* Linnaeus, 1758	Vulnerable (VU)
White-bellied sea eagles	*Haliaeetus leucogaster* (Gmelin, 1788)	Least Concern (LC)
Wagler pit viper	*Tropidolaemus wagleri* (Boie, 1827)	Least Concern (LC)
Gibbon	*Hylobates muelleri* Martin, 1841	Near Threatened (NT)
Long-tailed monkey	*Macaca fascicularis* (Raffles, 1821)	Near Threatened (NT)
Red langur	*Presbytis rubicunda* (Müller, 1838)	Vulnerable (VU)
Mantanani scop owl	*Otus mantananensis* (Sharpe, 1892)	Least Concern (LC)
Mouse deer	*Tragulus napu* (F.Cuvier, 1822)	Least Concern (LC)

Table 7. Aboveground carbon stock in the HCVF of an oil palm plantation in Kotawaringin Timur, Central Kalimantan

Parameter	Value
Forest type	Secondary dipterocarp forest
Sampling plots (n)	13
Total area (ha)	65
Mean carbon stock (tC ha^{-1})	191.44
Standard deviation (tC ha^{-1})	100.48
Total carbon stock (tC)	12,443.72
95% confidence interval (tC ha^{-1})	179.96-202.92

The occurrence of these forest-dependent and conservation-priority taxa supports the classification of the site under HCV 1 (species diversity) and HCV 3 (threatened habitats), while riparian and tidal forest areas correspond to HCV 4 (ecosystem services). When considered together with the floristic structure illustrated in Figure 4, these findings demonstrate that the HCVF provides not only suitable habitat for wildlife but also the structural conditions required to sustain trophic interactions and broader ecological processes within an intensive plantation landscape (Meijaard et al. 2018, 2020).

Carbon stock and comparison with regional forests

The estimated mean aboveground carbon stock of 191.44 tC ha^{-1} (Table 7) places the HCVF within the range reported for secondary Dipterocarp forests in Kalimantan and other parts of Borneo. Studies of intact primary Dipterocarp forests commonly report carbon stocks exceeding 250-300 tC ha^{-1}, whereas secondary forests typically range from 120 to 220 tC ha^{-1}, depending on recovery stage and disturbance history (Griscom et al. 2017). Although carbon stocks in the studied HCVF are lower than those of undisturbed primary forests, they remain substantial and ecologically significant. Secondary forests have been increasingly recognized as important carbon sinks, particularly when protected from further degradation and allowed to regenerate naturally (Poorter et al. 2016). Within oil palm concession landscapes, such carbon stocks represent meaningful contributions to emission mitigation and landscape-level climate regulation.

Biodiversity-carbon co-benefits

The coexistence of high tree diversity, structurally complex forest composition (Figure 4), and substantial carbon storage demonstrates clear biodiversity-carbon co-benefits within the HCVF. Global and regional studies have consistently shown positive relationships between tree species richness, functional diversity, and biomass carbon in tropical forests (Cavanaugh et al. 2014; Liang et al. 2016). Structurally diverse forests, characterized by multiple canopy layers and dominance of long-lived taxa such as Dipterocarpaceae, tend to allocate biomass more efficiently and exhibit greater ecological resilience. The results of this study therefore support integrated conservation approaches that prioritize both biodiversity and carbon storage within agricultural sustainability frameworks, particularly in oil palm landscapes where natural forest cover is limited (Meijaard et al. 2018; Edwards et al. 2019).

Table 5 shows a list of commercial tree species and is dominated by plants that serve as food for wildlife, especially primates, which are still found in the HCVF area. Table 6 shows a list of wildlife species found within the company's HCVF area, dominated by primates in accordance with the dominance of food trees found in Table 5, and some types of predatory birds such as eagles and owls which are deliberately kept by the company, as well as hornbills which are endemic species since the area was not yet opened for plantations.

Table 7 explains that data on carbon stock in the study area were collected in the form of sampling in several research plot areas with results obtained from secondary dipterocarpaceae forest areas, which were calculated using allometrics appropriate to the existing forest type.

Ecological and management implications

The findings of this study underscore the ecological importance of High Conservation Value Forests as multifunctional conservation units within oil palm plantation landscapes. The combination of high plant species diversity, structurally intact forest composition (Figure 4), the presence of protected wildlife, and substantial carbon stocks demonstrates that well-managed HCVFs can simultaneously support biodiversity conservation and climate regulation. From an ecological perspective, maintaining forest structure, species evenness, and key functional families such as Dipterocarpaceae is essential for sustaining ecosystem resilience, regeneration potential, and habitat quality.

From a management standpoint, these results highlight the need for strict protection of HCVFs from further degradation, including prevention of encroachment, fire, and selective logging. Enhancing connectivity between HCVFs and surrounding forested areas may further strengthen their role as wildlife corridors. Regular biodiversity and carbon monitoring using standardized methods is critical for evaluating management effectiveness and demonstrating compliance with sustainability certification schemes. Ultimately, the ecological functions provided by HCVFs enhance the environmental credibility of oil palm operations and contribute to broader national and global commitments to biodiversity conservation and climate change mitigation.

In conclusion, this study demonstrates that the High Conservation Value Forest (HCVF) within an oil palm plantation in Central Kalimantan retains substantial ecological value. Plant diversity was high at the tree level (H' = 3.31; evenness >0.70), with moderate seedling diversity, indicating a structurally intact secondary Dipterocarp forest. The presence of forest-dependent and protected fauna, including pangolins, hornbills, gibbons, and eagles, confirms its role as an effective wildlife habitat. The HCVF also stored considerably aboveground carbon (191.44 tC ha^{-1}), highlighting its contribution to landscape-level climate regulation. These findings show that company-managed HCVFs can deliver biodiversity conservation and carbon sequestration benefits simultaneously, supporting sustainable oil palm plantation management.

ACKNOWLEDGEMENTS

This research and publication were made possible through the full support of the Oil Palm Plantation Fund Management Agency (BPDPKS), Indonesia, with contract number: PRJ_171/DPKS/2024. We also gratefully acknowledge the support of a private oil palm company in Indonesia for providing access to the research site, accommodation facilities, and field assistance, which greatly contributed to the implementation of this study.

REFERENCES

Adinugroho WC, Prasetyo LB, Kusmana C, Krisnawati H, Weston CJ, Volkova L. 2022. Recovery of carbon and vegetation diversity 23 years after fire in a tropical dryland forest of Indonesia. Sustainability 14 (12): 6964. https://doi.org/10.3390/su14126964.

Afrianti S, Pakpahan EH. 2024. Structure and composition of tree vegetation in the high conservation value area of oil palm plantations. Jurnal Teknik Pertanian Lampung 13 (3): 805-816. http://doi.org/10.23960/jtep-l.v13i3.805-816.

Amit B, Klok WR, Van Der Meer PJ, Khairuddin NS, Yaman IC, Khoon KL. 2023. The effects of peat swamp forest patches and riparian areas within large scale oil palm plantations on bird species richness. Trop Life Sci Res 34 (2): 131. https://doi.org/10.21315/tlsr2023.34.2.7.

Amri I, Widura E, Iqbal M, Andika Y, Izzatillah AR. 2023. Distribution of oil palm plantations and their suitability with spatial planning: An assessment in Aceh, Indonesia. BIO Web Conf 80: 02006. https://doi.org/10.1051/bioconf/20238002006.

Anand MO, Krishnaswamy J, Kumar A, Bali A. 2010. Sustaining biodiversity conservation in human-modified landscapes in the Western Ghats: Remnant forests matter. Biol Conserv 143 (10): 2363-2374. https://doi.org/10.1016/j.biocon.2010.01.013.

Anderson JA, McClean CJ, Sim S, Pettorelli N, Jelling A, Tangah J, Hill JK. 2022. Weak edge effects on trees in Bornean rainforest remnants bordering oil palm. Biotropica 54 (4): 921-932. https://doi.org/10.1111/btp.13115.

Ang CC, O'brien MJ, Ng KK, Lee PC, Hector A, Schmid B, Shimizu KK. 2016. Genetic diversity of two tropical tree species of the Dipterocarpaceae following logging and restoration in Borneo: High genetic diversity in plots with high species diversity. Plant Ecol Divers 9 (5-6): 459-469. http://doi.org/10.1080/17550874.2016.1270363.

Austin KG, Lee ME, Clark C, Forester BR, Urban DL, White L, Kasibhatla PS, Poulsen JR. 2017. An assessment of high carbon stock and high conservation value approaches to sustainable oil palm cultivation in Gabon. Environ Res Lett 12 (1): 014005. https://doi.org/10.1088/1748-9326/aa5437.

Basyuni M, Slamet B, Sulistiyono N, Thoha AS, Bimantara Y, Widjaja EA. 2019. Species composition and plant diversity of logged-over forest in Sikundur, Gunung Leuser National Park, North Sumatra. IOP Conf Ser: Earth Environ Sci 374: 012051. https://doi.org/10.1088/1755-1315/374/1/012051.

Budiharta S. 2010. Floristic composition at biodiversity protection area in Lubuk Kakap, District of Ketapang, West Kalimantan. Biodiversitas 11 (3): 151-156. https://doi.org/10.13057/biodiv/d110309.

Cavanaugh KC, Gosnell JS, Davis SL, Ahumada J, Boundja P, Clark DB, Mugerwa B, Jansen PA, O'Brien TG, Rovero F, Sheil D. 2014. Carbon storage in tropical forests correlates with taxonomic diversity and functional dominance on a global scale. Glob Ecol Biogeogr 23 (5): 563-573. https://doi.org/10.1111/geb.12143

Chisholm PJ, Gray AN. 2024. Forest carbon sequestration on the west coast, USA: Role of species, productivity, and stockability. PLoS One 19 (5): e0302823. https://doi.org/10.1371/journal.pone.0302823.

Deere NJ, Guillera-Arroita G, Baking EL, Bernard H, Pfeifer M, Reynolds G, Wearn OR, Davies ZG, Struebig MJ. 2018. High carbon stock forests provide co-benefits for tropical biodiversity. J Appl Ecol 55 (2): 997-1008. https://doi.org/10.1111/1365-2664.13023.

Drewer J, Leduning MM, Griffiths RI, Goodall T, Levy PE, Cowan N, Comynn-Platt E, Hayman G, Sentian J, Majalap N, Skiba UM. 2021. Comparison of greenhouse gas fluxes from tropical forests and oil palm plantations on mineral soil. Biogeosciences 18: 1559-1575. https://doi.org/10.5194/bg-18-1559-2021.

Drewer J, Tarigan RS, Banin LF, White S, Raine E, Luke SH, Turner EC, Skiba U, Cowan NJ, Dewi JP, Advento AD, Aryawan AAK, Caliman JP, Pujianto. 2024. Restoring understory and riparian areas in oil palm plantations does not increase greenhouse gas fluxes. Front For Glob Change 7: 1324475. https://doi.org/10.3389/ffgc.2024.1324475.

Edwards DP, Socolar JB, Mills SC, Burivalova Z, Koh LP, Wilcove DS. 2019. Conservation of tropical forests in the Anthropocene. Curr Biol 29 (19): R1008-R1020. https://doi.org/10.1016/j.cub.2019.08.026.

Erniwati, Zuhud E, Santosa Y, Anas I. 2016. The value of secondary forest patches for bird conservation in palm oil landscapes of Riau, Sumatra. Biodiversitas 17 (2): 791-798. https://doi.org/10.13057/biodiv/d170256.

Fiqa AP, Fauziah, Lestari DA, Budiharta S. 2018. The importance of in-situ conservation area in mining concession in preserving diversity, threatened and potential floras in East Kalimantan, Indonesia. Biodiversitas 20 (1): 198-210. https://doi.org/10.13057/biodiv/d200123.

Fleiss S, Waddell EH, Ola BB, Banin LF, Benedick S, Sailim AB, Chapman DS, Jelling A, King H, McClean CJ, Yeong KL, Hill JK. 2020. Conservation set-asides improve carbon storage and support associated plant diversity in certified sustainable oil palm plantations. Biol Conserv 248: 108631. https://doi.org/10.1016/j.biocon.2020.108631.

Gibson L, Lee TM, Koh LP, Brook BW, Gardner TA, Barlow J, Peres CA, Bradshaw CJ, Laurance WF, Lovejoy TE, Sodhi NS. 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature 478 (7369): 378-381. https://doi.org/10.1038/nature10425.

Griscom BW, Adams J, Ellis PW, Houghton RA, Lomax G, Miteva DA, Schlesinger WH, Shoch D, Siikamäki JV, Smith P, Zganjar C, Blackman A, Campari J, Conant RT, Delgado C, Elias P et al. 2017. Natural climate solutions. Proc Natl Acad Sci USA 114 (44): 11645-11650. https://doi.org/10.1073/pnas.1710465114.

Gunawan H, Setyawati T, Atmoko T, Kwatrina RT, Yeny I, Yuwati TW, Effendy R, Abdullah L, Lastini T, Arini DI, Sari UK, Sitepu BS, Pattiselanno F, Kuswanda W. 2024. A review of forest fragmentation in Indonesia under the DPSIR framework for biodiversity conservation strategies. Glob Ecol Conserv 51: e02918. https://doi.org/10.1016/j.gecco.2024.e02918.

Hayward RM, Banin LF, Burslem DF, Chapman DS, Philipson CD, Cutler ME, Reynolds G, Nilus R, Dent DH. 2021. Three decades of post-logging tree community recovery in naturally regenerating and actively restored dipterocarp forest in Borneo. For Ecol Manag 488: 119036. https://doi.org/10.1016/j.foreco.2021.119036.

Herningtyas W. 2021. Conflict of palm oil companies with indigenous people and forest surrounding society. BHUMI: Jurnal Agraria dan Pertanahan 7 (2): 199-209. https://doi.org/10.31292/bhumi.v7i2.504.

Hua F, Liu M, Wang Z. 2024. Integrating forest restoration into land-use planning at large spatial scales. Curr Biol 34 (9): R452-R472. https://doi.org/10.1016/j.cub.2024.02.034.

Kasper K, Devriance N, Aran K, Martin B. 2024. Conservation among oil palm plantations? Mammalian diversity in protected forest areas of a mixed-use landscape in Indonesian Borneo. Anim Biodivers Conserv 47 (2): 123-134. https://doi.org/10.32800/abc.2024.47.0123.

Kristianto PH. 2025. Planting exceptional tropical tree species to enhance long-term carbon storage in assisted secondary succession: Practical approach to develop legal norm. IOP Conf Ser: Earth Environ Sci 1447: 012010. https://doi.org/10.1088/1755-1315/1447/1/012010.

Kwatrina RT, Santosa Y, Bismark M, Santoso N. 2018. Tropical plant diversity of Borneo: The role of high conservation value area on species conservation in an oil palm plantation. AIP Conf Proc 2019 (1): 040012. https://doi.org/10.1063/1.5061882.

Liang J, Crowther TW, Picard N, Wiser S, Zhou M, Alberti G, Schulze ED, McGuire AD, Bozzato F, Pretzsch H, de-Miguel S, Paquette A, Hérault B, Scherer-Lorenzen M, Barrett CB, Glick HB, Hengeveld GM, Nabuurs GJ, Pfautsch S, Viana H, et al. 2016. Positive biodiversity-productivity relationship predominant in global forests. Science 354 (6309): aaf8957. https://doi.org/10.1126/science.aaf8957.

Luskin MS, Brashares JS, Ickes K, Sun IF, Fletcher C, Wright SJ, Potts MD. 2017. Cross-boundary subsidy cascades from oil palm degrade distant tropical forests. Nat Commun 8 (1): 2231. https://doi.org/10.1038/s41467-017-01920-7.

Maimunah S, Hanafi I, Subhan, Anhar A, Samek JH. 2021. An assessment of tree biodiversity and carbon stocks in mangrove forests, Langsa City, Aceh, Indonesia. IOP Conf Ser: Earth Environ Sci 886: 012085. https://doi.org/10.1088/1755-1315/886/1/012085.

Maimunah S, Nugraha NS, Noviyanto AN, Jaya GI, Handru A, Samek JH. 2024. Assessment of tree biodiversity and carbon stocks in Rangan Hiran Social Forestry Area, Gunung Mas, Indonesia. Borneo J Resour Sci Technol 45 (1): 1-9. https://doi.org/10.51200/bsj.v45i1.5480.

Meijaard E, Brooks TM, Carlson KM, Slade EM, Garcia-Ulloa J, Gaveau DLA, Lee JSH, Santika T, Juffe-Bignoli D, Struebig MJ, Wich SA, Ancrenaz M, Koh LP, Zamira N, Abrams JF, Prins HHT, Sendashonga CN, Murdiyarso D, Furumo PR, Macfarlane N, Hoffmann R, Persio M, Descals A, Szantoi Z, Sheil D. 2020. The environmental impacts of palm oil in context. Nat Plants 6 (12): 1418-1426. https://doi.org/10.1038/s41477-020-00813-w.

Meijaard E, Carlson KM, Garcia U, Sheil D, Juffe-Bignoli D, Wich S. (eds). 2018. Oil Palm and Biodiversity: A Situation Analysis by the IUCN Oil Palm Task Force. IUCN, International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2018.11.en.

Mijiarto J, Arief H, Purnamasari I. 2023. The roles of high conservation value area to support biodiversity conservation in Indonesia. IOP Conf Ser: Earth Environ Sci 1243: 012002. https://doi.org/10.1088/1755-1315/1243/1/012002.

Mitchell SL, Edwards DP, Bernard H, Coomes D, Jucker T, Davies ZG, Struebig MJ. 2018. Riparian reserves help protect forest bird communities in oil palm dominated landscapes. J Appl Ecol 55 (6): 2744-2755. https://doi.org/10.1111/1365-2664.13233.

Mohd-Azlan J. 2019. The role of forest fragments in small mammal conservation in an oil palm plantation in northern Sarawak, Borneo. J Oil Palm Res 31 (3): 422-436. https://doi.org/10.21894/jopr.2019.0034.

Mukul SA, Herbohn J, Firn J. 2020. Rapid recovery of tropical forest diversity and structure after shifting cultivation in the Philippines uplands. Ecol Evol 10 (14): 7189-7211. https://doi.org/10.1002/ece3.6419.

Nasution ED, Saidy AR, Priatmadi BJ, Hafizianor, Suwardi, Sukarman, Dasrial Moch, Alfiana HU, Jailani R. 2023. Analysis of vegetation and plant diversity in high conservation value areas in oil palm plantations. Plant Sci Today 11 (1): 296-307. https://doi.org/10.14719/pst.2924.

Ng KKS, Kobayashi MJ, Fawcett JA, Hatakeyama M, Paape T, Ng CH, Ang CC, Tnah LH, Lee CT, Nishiyama T, Sese J, O'Brien MJ, Copetti D, Isa MNM, Ong RC, Putra M, Siregar IZ, Indrioko S, Kosugi Y, Izuno A, Isagi Y, Lee SL, Shimizu KK. 2021. The genome of *Shorea leprosula* (Dipterocarpaceae) highlights the ecological relevance of drought in aseasonal tropical rainforests. Commun Biol 4 (1): 1166. https://doi.org/10.1038/s42003-021-02682-1.

Nunes MH, Jucker T, Riutta T, Svátek M, Kvasnica J, Rejžek M, Matula R, Majalap N, Ewers RM, Swinfield T, Valbuena R, Vaughn NR, Asner GP, Coomes DA. 2021. Recovery of logged forest fragments in a human-modified tropical landscape during the 2015-16 El Niño. Nat Commun 12 (1): 1526. https://doi.org/10.1038/s41467-020-20811-y.

Ocampo-Peñuela N, Garcia-Ulloa J, Kornecki I, Philipson CD, Ghazoul J. 2020. Impacts of four decades of forest loss on vertebrate functional habitat on Borneo. Front For Glob Change 3: 53. https://doi.org/10.3389/ffgc.2020.00053.

Ordway EM, Asner GP. 2020. Carbon declines along tropical forest edges correspond to heterogeneous effects on canopy structure and function. Proc Natl Acad Sci USA 117 (14): 7863-7870. https://doi.org/10.1073/pnas.1914420117.

Poorter L, Bongers F, Aide TM, Almeyda Zambrano AM, Balvanera P, Becknell JM, Boukili V, Brancalion PH, Broadbent EN, Chazdon RL, Craven D, de Almeida-Cortez JS, Cabral GA, de Jong BH, Denslow JS, Dent DH, DeWalt SJ, Dupuy JM, Durán SM, Espírito-Santo MM, et al. 2016. Biomass resilience of Neotropical secondary forests. Nature 530 (7589): 211-214. https://doi.org/10.1038/nature16512.

Pransiska Y, Triadiati T, Tjitrosoedirjo S, Hertel D, Kotowska MM. 2016. Forest conversion impacts on the fine and coarse root system, and soil organic matter in tropical lowlands of Sumatera (Indonesia). For Ecol Manag 379: 288-298. https://doi.org/10.1016/j.foreco.2016.07.038.

Prohaska A, Seddon AWR, Rach O, Smith A, Sachse D, Willis KJ. 2023. Long-term ecological responses of a lowland dipterocarp forest to climate changes and nutrient availability. New Phytol 240 (6): 2513-2529. https://doi.org/10.1111/nph.19169.

Pusparini W, Cahyana A, Grantham HS, Maxwell S, Soto-Navarro C, Macdonald DW. 2023. A bolder conservation future for Indonesia by prioritising biodiversity, carbon and unique ecosystems in Sulawesi. Sci Rep 13 (1): 842. https://doi.org/10.1038/s41598-022-21536-2.

Qie L, Elsy AD, Stumvoll A, Kwasnicka M, Peel AL, Sullivan JA, Ettinger MS, Robertson AJ, Brisbane JK, Sawyer AL, Lui YN, Ngim Ow S, Sebastianelli M, Majcher B, Duan M, Vigus H, Pounsin G, Nilus R, Ewers R. 2019. Impending regeneration failure of the IUCN vulnerable Borneo ironwood (*Eusideroxylon zwageri*). Trop Conserv Sci 2019: 12. https://doi.org/10.1177/1940082918823353.

Rahayu S, Pambudi S, Permadi D, Tata HL, Martini E, Rasnovi S, Nuroniah HS, Kindt R, Nugraha M, Dewi S, van Noordwijk M. 2022. Functional trait profiles and diversity of trees regenerating in disturbed tropical forests and agroforests in Indonesia. For Ecosyst 9: 100030. https://doi.org/10.1016/j.fecs.2022.100030.

Ramlah S, Santosa Y, Ihsan M, Reinaldi. 2024. Prospect of the high conservation value areas as tourisms destination in the oil palm plantation, Pasangkayu Regency, West Sulawesi, Indonesia. IOP Conf Ser: Earth Environ Sci 1366: 012025. https://doi.org/10.1088/1755-1315/1366/1/012025.

Rodríguez-León CH, Roa-Fuentes LL, Sterling A, Suárez JC. 2022. Plant biodiversity homogenization across the chronosequence in highly fragmented landscapes in the Colombian Andean-Amazonian transition. Forests 13 (9): 1422. https://doi.org/10.3390/f13091422.

Sahana M, Areendran G, Sivadas A, Masroor M, Abhijita CS, Raj K, Ranjan K, Sharma D, Sultan MS, Ghoshal A, Parameswaran S, Sajjad H, Deb S, Imdad K. 2025. A mixed-methods approach for identifying high conservation value areas in the high-altitude landscapes of the Indian Himalayan region. Geo: Geogr Environ 12 (1): e70002. https://doi.org/10.1002/geo2.70002.

Scriven SA, Carlson KM, Hodgson JA, McClean CJ, Heilmayr R, Lucey JM, Hill JK. 2019. Testing the benefits of conservation set-asides for improved habitat connectivity in tropical agricultural landscapes. J Appl Ecol 56 (10): 2274-2285. https://doi.org/10.1111/1365-2664.13472.

Scriven SA, Gillespie GR, Laimun S, Goossens B. 2018. Edge effects of oil palm plantations on tropical anuran communities in Borneo. Biol Conserv 220: 37-49. https://doi.org/10.1016/j.biocon.2018.02.006.

Scriven SA, Hodgson JA, McClean CJ, Hill JK. 2015. Protected areas in Borneo may fail to conserve tropical forest biodiversity under climate change. Biol Conserv 184: 414-423. https://doi.org/10.1016/j.biocon.2015.02.018.

Senior MJ, Brown E, Villalpando P, Hill JK. 2015. Increasing the scientific evidence base in the "High Conservation Value" (HCV) approach for biodiversity conservation in managed tropical landscapes. Conserv Lett 8 (5): 361-367. https://doi.org/10.1111/conl.12148.

Simamora TI, Purbowo SD, Laumonier Y. 2021. Looking for indicator bird species in the context of forest fragmentation and isolation in West Kalimantan, Indonesia. Glob Ecol Conserv 27: e01610. https://doi.org/10.1016/j.gecco.2021.e01610.

Slik JW, Arroyo-Rodríguez V, Aiba S, Alvarez-Loayza P, Alves LF, Ashton P, Balvanera P, Bastian ML, Bellingham PJ, et al. 2015. An estimate of the number of tropical tree species. Proc Natl Acad Sci USA 112 (24): 7472-7477. https://doi.org/10.1073/pnas.1423147112.

Stride G, Thomas CD, Benedick S, Hodgson JA, Jelling A, Senior MJ, Hill JK. 2018. Contrasting patterns of local richness of seedlings, saplings, and trees may have implications for regeneration in rainforest remnants. Biotropica 50 (6): 889-897. https://doi.org/10.1111/btp.12605.

Tng DY, Apgaua DM, Campbell MJ, Cox CJ, Crayn DM, Ishida FY, Laidlaw MJ, Liddell MJ, Seager M, Laurance SG. 2016. Vegetation and floristics of a lowland tropical rainforest in northeast Australia. Biodivers Data J 4: e7599. https://doi.org/10.3897/BDJ.4.e7599.

Tuan NT, Rodríguez-Hernández DI, Tuan VC, Quy NV, Obiakara MC, Hufton J. 2022. Effects of tree diversity and stand structure on above-ground carbon storage in evergreen broad-leaved and deciduous forests in Southeast Vietnam. Dendrobiology 88: 38-55. https://doi.org/10.12657/denbio.088.003.

Waddell EH, Banin LF, Fleiss S, Hill JK, Hughes M, Jelling A, Yeong KL, Ola BB, Sailim AB, Tangah J, Chapman DS. 2020. Land-use change and propagule pressure promote plant invasions in tropical rainforest remnants. Landsc Ecol 35: 1891-1906. https://doi.org/10.1007/s10980-020-01067-9.

William WO, van Manen FT, Sharp SP, Ratnayeke S. 2023. Secondary forest within a timber plantation concession in Borneo contributes to a diverse mammal assemblage. Glob Ecol Conserv 43: e02474. https://doi.org/10.1016/j.gecco.2023.e02474.

Wolff S, Schweinle J. 2022. Effectiveness and economic viability of forest certification: A systematic review. Forests 13 (5): 798. https://doi.org/10.3390/f13050798.